KEMENTERIAN PENGAJIAN TINGGI
JABATAN PENDIDIKAN POLITEKNIK DAN KOLEJ KOMUNITI

POLITEKNIK MALAYSIA
KUALA TERENGGANU

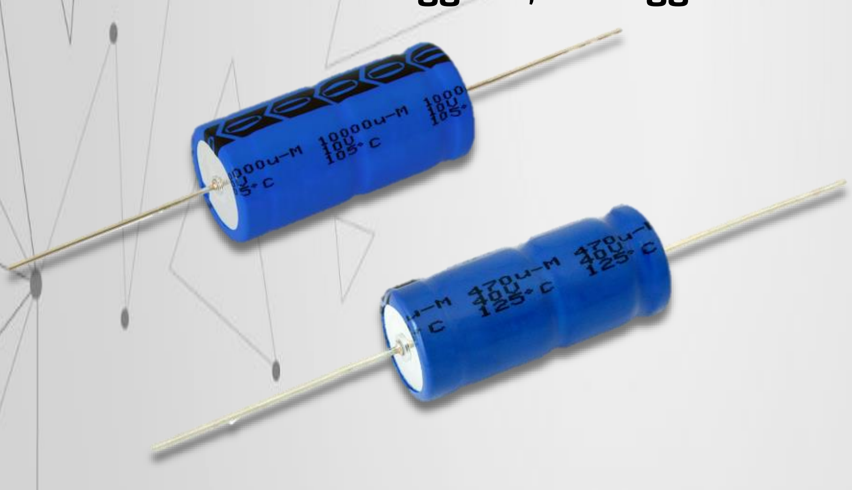
CAPACITOR & CAPACITANCE

MOHD FAHMI BIN ABDUL LATIF
Politeknik Kuala Terengganu

CAPACITOR AND CAPACITANCE

One of the topic in Electrical Technology

By:
Mohd Fahmi bin Abdul Latif
Department of Electrical Engineering
Politeknik Kuala Terengganu, Terengganu



First Edition published 2022

Publish by:

Politeknik Kuala Terengganu 20200 Jalan Sultan Ismail Kuala Terengganu, Terengganu 09-6204100

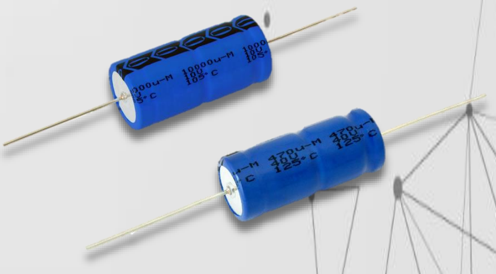
e ISBN 978-967-2240-38-9

9 7 8 9 6 7 2 2 4 0 3 8 9

CAPACITOR AND CAPACITANCE

Perpustakaan Negara Malaysia Cataloguing-in-Publication Data

Mohd. Fahmi Abdul Latif, 1983-
CAPACITOR AND CAPACITANCE / Penulis: MOHD FAHMI BIN ABDUL LATIF.
Mode of access: Internet
eISBN 978-967-2240-38-9
1. Capacitors.
2. Capacitance meters.
3. Government publications--Malaysia.
4. Electronic books.
I. Title.
621.315



PREFACE

In the name of Allah, The Most Gracious, The Most Merciful. Author deepest gratitude extends to Allah S.W.T for every patience, strength, determination and courage to carry out the writing of this **Capacitor & Capacitance** e-book.

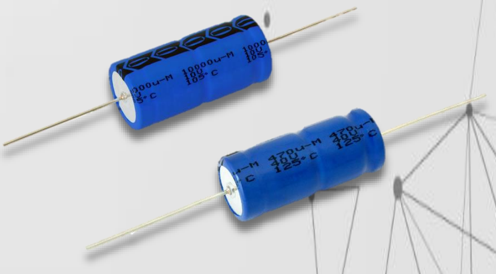
Many thanks and appreciation are extended to all colleagues of the Department of Electrical and Electronic, Politeknik Kuala Terengganu for their views, helpful cooperation and encouraging comments. Finally, we are very proud and hope that this e-book can benefit the community, especially students and lecturers.

Thank you.

CAPACITOR AND CAPACITANCE

Suitable for diploma students, this book concise for students to understand the characteristics of Capacitor in electrical engineering. It contains basic theory and practical foundations for capacitance in electronics circuit.

TABLE OF CONTENTS



1.0

INTRODUCTION

A capacitor essentially consists of two conducting surfaces separated by a layer of an insulating medium called dielectric. The conducting surfaces may be in the form of either circular (or rectangular) plates or be of spherical or cylindrical shape. The purpose of a capacitor is to store electrical energy by electrostatic stress in the dielectric.

1.1 Capacitor

A capacitor is a device which stores electric charge. Capacitors vary in shape and size, but the basic configuration is two conductors carrying equal but opposite charges (Figure 1.1). Capacitors have many important applications in electronics. Some examples include storing electric potential energy, delaying voltage changes when coupled with resistors, filtering out unwanted frequency signals, forming resonant circuits and making frequency-dependent and independent voltage dividers when combined with resistors. Some of these applications will be discussed in latter chapters.

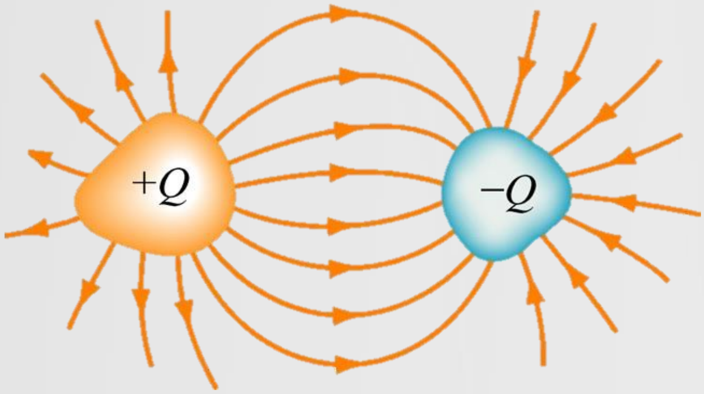


Figure 1.1: Basic configuration of a capacitor.

In the uncharged state, the charge on either one of the conductors in the capacitor is zero. During the charging process, a charge Q is moved from one conductor to the other one, giving one conductor a charge +Q , and the other one a charge -Q . A potential difference, ΔV is created, with the positively charged conductor at a higher potential than the negatively charged conductor.

Note that whether charged or uncharged, the net charge on the capacitor as a whole is zero.

The simplest example of a capacitor consists of two conducting plates of area A , which are parallel to each other, and separated by a distance d, as shown in Figure 1.2.

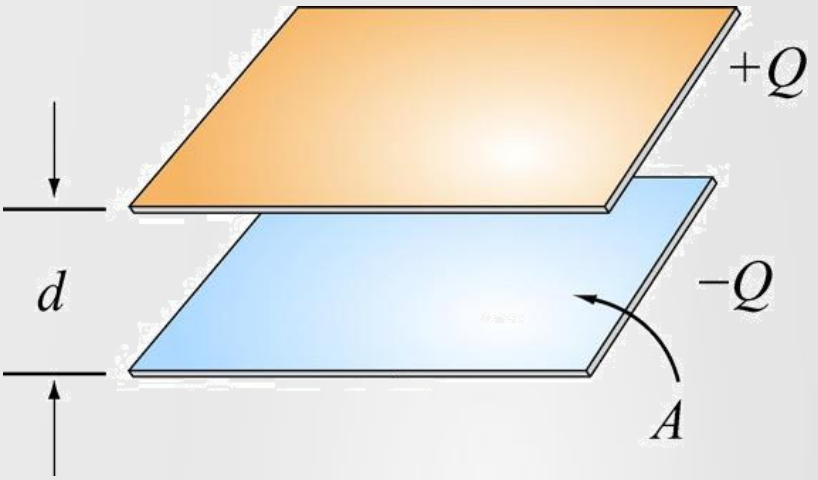


Figure 1.2: A parallel-plate capacitor

Experiments show that the amount of charge *Q* stored in a capacitor is linearly proportional to ΔV , the electric potential difference between the plates. Thus, we may write

$$Q = C\,|\,\Delta V\,|$$

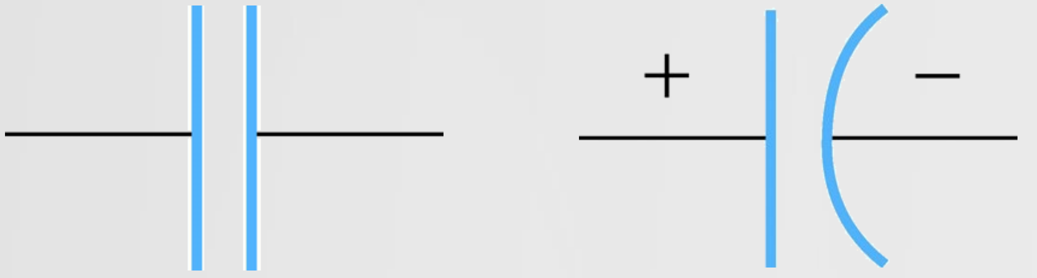
where *C* is a positive proportionality constant called *capacitance*.

Physically, capacitance is a measure of the capacity of storing electric charge for a given potential difference ΔV. The SI unit of capacitance is the farad (F):

$$1 \text{ F} = 1 \text{ farad} = 1 \text{coulomb/volt} = 1 \text{C/V}$$

A typical capacitance is in the picofarad ($1\text{pF} = 10^{-12}\text{F}$) to millifarad range, ($1\text{mF} = 10^{-3}\text{F} = 1000\mu\text{F}$; $1\mu\text{F} = 10^{-6}\text{F}$).

Figure 1.3(a) shows the symbol which is used to represent capacitors in circuits. For a polarized fixed capacitor which has a definite polarity, Figure 1.3(b) is sometimes used.



(a) (b)

Figure 1.3: Capacitor symbols.

2.0

CALCULATION OF CAPACITANCE

The property of a capacitor to ‘store electricity’ may be called its capacitance. Let’s see how capacitance can be computed in systems with simple geometry.

2.1 Parallel-Plate Capacitor

Consider two metallic plates of equal area A separated by a distance d, as shown in Figure 2.1 below. The top plate carries a charge +Q while the bottom plate carries a charge –Q. The charging of the plates can be accomplished by means of a battery which produces a potential difference.

To find the capacitance C, we first need to know the electric field between the plates. A real capacitor is finite in size. Thus, the electric field lines at the edge of the plates are not straight lines, and the field is not contained entirely between the plates.

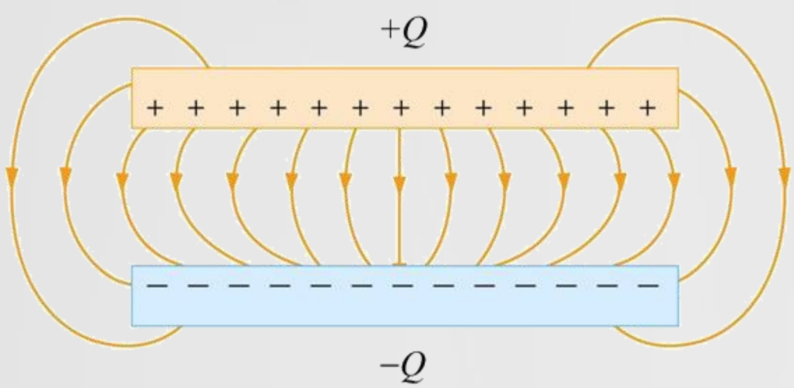
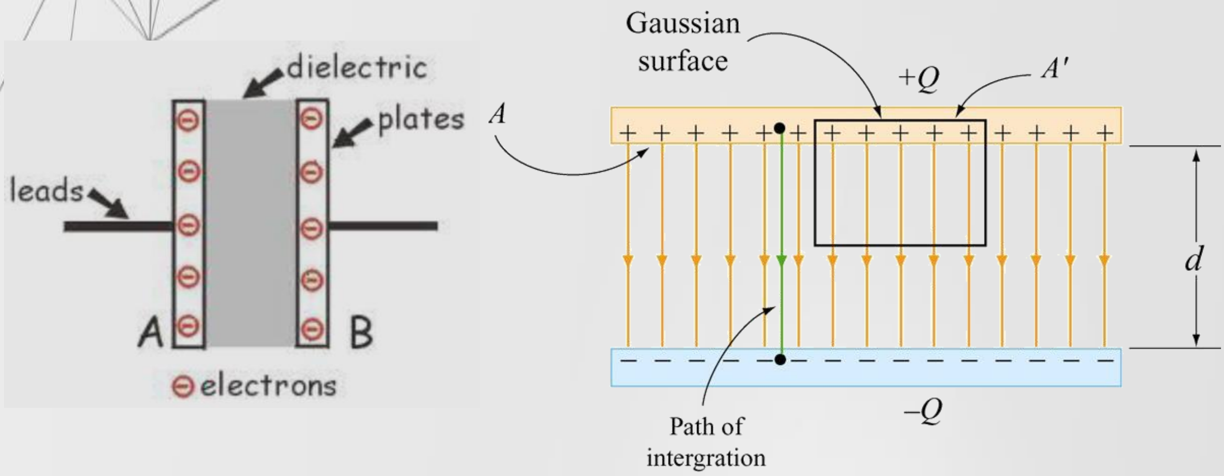


Figure 2.1: The electric field between the plates of a parallel-plate capacitor

From the definition of capacitance, we have the potential difference between the plates is

$$\boxed{C = \frac{Q}{|\Delta V|} = \frac{\varepsilon_0 A}{d} \qquad \text{(parallel plate)}}$$

Note that C depends only on the geometric factors A and d. The capacitance C increases linearly with the area A since for a given potential difference ΔV, a bigger plate can hold more charge. On the other hand, C is inversely proportional to d, the distance of separation because the smaller the value of d, the smaller the potential difference $|\Delta V|$ for a fixed Q.



(a) (b)

Figure 2.2: The electric field between the plates.

In its simplest form, a capacitor is an electrical device that stores electrical charge and is constructed of two parallel conductive plates separated by an insulating material called the **dielectric**. Connecting leads are attached to the parallel plates. A basic capacitor is shown in the Figure 2.2 (b).

3.0

CAPACITORS IN ELECTRIC CIRCUITS

A capacitor can be charged by connecting the plates to the terminals of a battery, which are maintained at a potential difference ΔV called the **terminal voltage**.

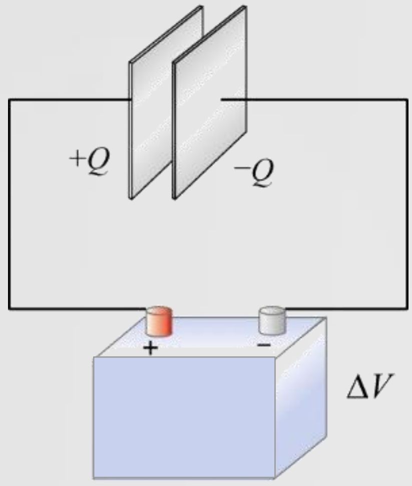


Figure 3.1: Charging a capacitor

The connection results in sharing the charges between the terminals and the plates. For example, the plate that is connected to the (positive) negative terminal will acquire some (positive) negative charge. The sharing causes a momentary reduction of charges on the terminals, and a decrease in the terminal voltage.

Chemical reactions are then triggered to transfer more charge from one terminal to the other to compensate for the loss of charge to the capacitor plates, and maintain the terminal voltage at its initial level. The battery could thus be thought of as a charge pump that brings a charge Q from one plate to the other.

3.1 Parallel Connection

Suppose we have two capacitors C_1 with charge Q_1 and C_2 with charge Q_2 that are connected in parallel, as shown in Figure 3.2.

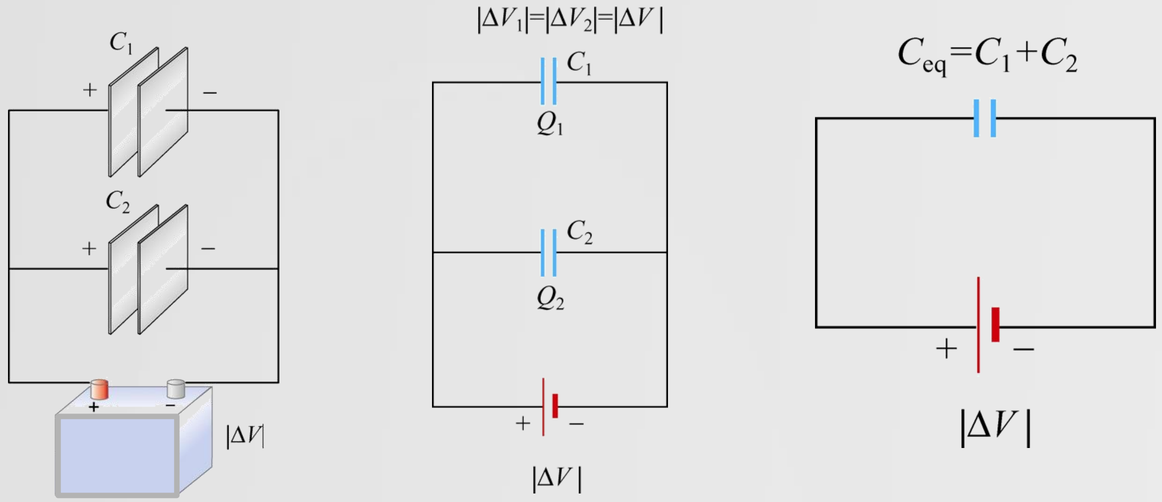


Figure 3.2: Capacitors in parallel and an equivalent capacitor.

The left plates of both capacitors C_1 and C_2 are connected to the positive terminal of the battery and have the same electric potential as the positive terminal. Similarly, both right plates are negatively charged and have the same potential as the negative terminal. Thus, the potential difference $|\Delta V|$ is the same across each capacitor. This gives

$$C_1 = \frac{Q_1}{|\Delta V|}, \qquad C_2 = \frac{Q_2}{|\Delta V|}$$

These two capacitors can be replaced by a single equivalent capacitor Ceq with a total charge Q supplied by the battery. However, since Q is shared by the two capacitors, we must have

$$Q = Q_1 + Q_2 = C_1 |\Delta V| + C_2 |\Delta V| = \left(C_1 + C_2 \right) |\Delta V|$$

The equivalent capacitance is then seen to be given by

$$C_{\text{eq}} = \frac{Q}{|\Delta V|} = C_1 + C_2$$

Thus, capacitors that are connected in parallel add. The generalization to any number of capacitors is

$$C_{\text{eq}} = C_1 + C_2 + C_3 + \cdots + C_N$$

3.2 Series Connection

Suppose two initially uncharged capacitors C_1 and C_2 are connected in series, as shown in Figure 3.3. A potential difference $|\Delta V|$ is then applied across both capacitors. The left plate of capacitor 1 is connected to the positive terminal of the battery and becomes positively charged with a charge $+Q$, while the right plate of capacitor 2 is connected to the negative terminal and becomes negatively charged with charge $-Q$ as electrons flow in. What about the inner plates? They were initially uncharged; now the outside plates each attract an equal and opposite charge. So the right plate of capacitor 1 will acquire a charge $-Q$ and the left plate of capacitor $+Q$.

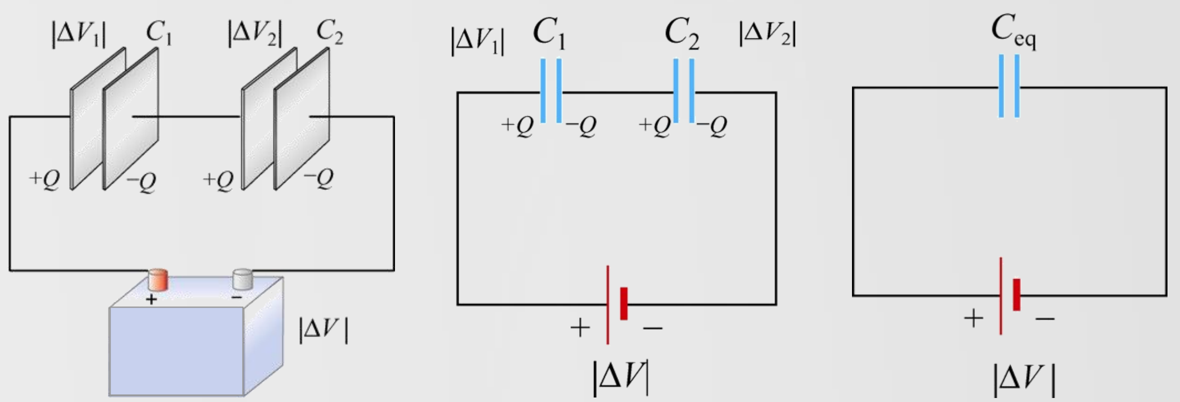


Figure 3.3: Capacitors in series and an equivalent capacitor

The potential differences across capacitors C_1 and C_2 are

$$|\Delta V_1| = \frac{Q}{C_1}, \quad |\Delta V_2| = \frac{Q}{C_2}$$

respectively. From Figure 3.3, we see that the total potential difference is simply the sum of the two individual potential differences:

$$\frac{Q}{C_{eq}} = \frac{Q}{C_1} + \frac{Q}{C_2}$$

and so the equivalent capacitance for two capacitors in series becomes

$$\frac{1}{C_{\mathrm{eq}}} = \frac{1}{C_1} + \frac{1}{C_2}$$

The generalization to any number of capacitors connected in series is

$$\frac{1}{C_{\mathrm{eq}}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_N}$$

Example 3.1 Equivalent Capacitance

Find the equivalent capacitance for the combination of capacitors shown in Figure 3.4

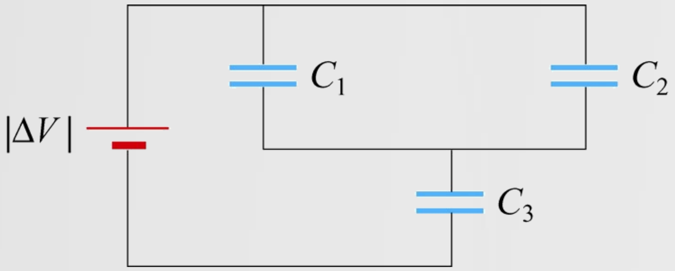


Figure 3.4 (a) Capacitors connected in series and in parallel

Solution

The simplify circuit is shown in Figure 3.4 (b) and (c). Since C_1 and C_2 are connected in parallel, their equivalent capacitance C_{12} is given by

$$C_{12} = C_1 + C_2$$

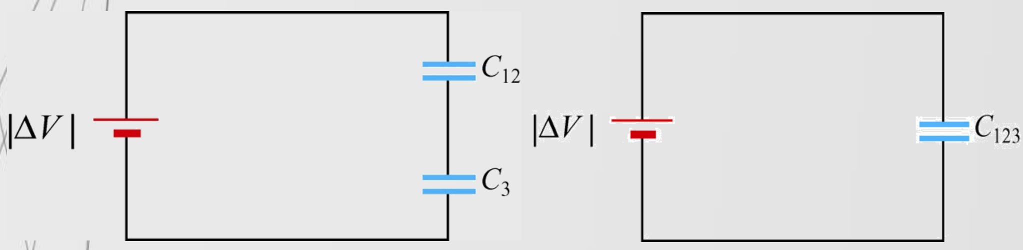


Figure 3.4 (b) and (c) Equivalent circuits.

Now capacitor C_{12} is in series with C_3, as seen from Figure 5.3.4(b). So, the equivalentcapacitance C_{123} is given by

$$\frac{1}{C_{123}} = \frac{1}{C_{12}} + \frac{1}{C_3}$$

$$C_{123} = \frac{C_{12}C_3}{C_{12} + C_3} = \frac{(C_1 + C_2)C_3}{C_1 + C_2 + C_3}$$

Example 3.2 Equivalent Capacitance

Consider the configuration shown in Figure 5.10.1. Find the equivalent capacitance, assuming that all the capacitors have the same capacitance *C*.

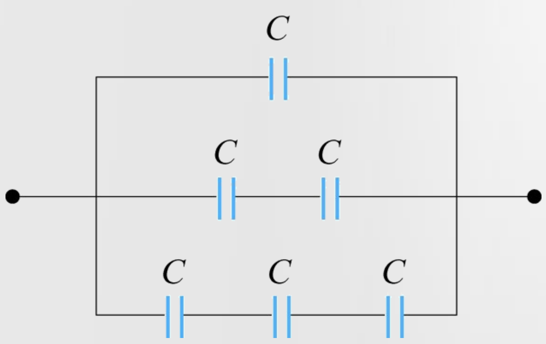


Figure 3.5 Combination of Capacitors

Solution

For capacitors that are connected in series, the equivalent capacitance is

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots \quad \text{(series)}$$

On the other hand, for capacitors that are connected in parallel, the equivalent capacitance is

$$C_{eq} = C_1 + C_2 + C_3 + \cdots \quad \text{(parallel)}$$

Using the above formula for series connection, the equivalent configuration is shown in Figure 3.6

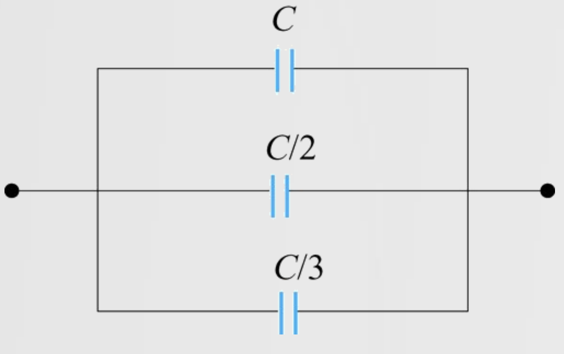


Figure 3.6: The equivalent configuration

Now we have three capacitors connected in parallel. The equivalent capacitance is given by

$$C_{eq} = C\left(1 + \frac{1}{2} + \frac{1}{3}\right) = \frac{11}{6}C$$

4.0
DIELECTRICS

In many capacitors there is an insulating material such as paper or plastic between the plates. Such material, called a dielectric, can be used to maintain a physical separation of the plates. Since dielectrics break down less readily than air, charge leakage can be minimized, especially when high voltage is applied.

Experimentally it was found that capacitance C increases when the space between the conductors is filled with dielectrics. To see how this happens, suppose a capacitor has a capacitance C_0 when there is no material between the plates. When a dielectric material is inserted to completely fill the space between the plates, the capacitance increases to

$$C = \kappa_e C_0$$

where κ_e is called the dielectric constant. In the Table below, we show some dielectric materials with their dielectric constant. Experiments indicate that all dielectric materials have $\kappa_e > 1$. Note that every dielectric material has a characteristic dielectric strength which is the maximum value of electric field before breakdown occurs and charges begin to flow.

TABLE 4.1 Some dielectric materials properties

Material	κ_e	Dielectric strength (106 V / m)
Air	1.00059	3
Paper	3.7	16
Glass	4 - 6	9
Water	80	-

The fact that capacitance increases in the presence of a dielectric can be explained from a molecular point of view. We shall show that κ_e is a measure of the dielectric response to an external electric field.

4.1 Permittivity

As well as the overall size of the conductive plates and their distance or spacing apart from each other, another factor which affects the overall capacitance of the device is the type of dielectric material being used. In other words, the "Permittivity" (ε) of the dielectric.

The conductive plates of a capacitor are generally made of a metal foil or a metal film allowing for the flow of electrons and charge, but the dielectric material used is always an insulator. The various insulating materials used as the dielectric in a capacitor differ in their ability to block or pass an electrical charge.

This dielectric material can be made from a number of insulating materials or combinations of these materials with the most common types used being: air, paper, polyester, polypropylene, Mylar, ceramic, glass, oil, or a variety of other materials.

The factor by which the dielectric material, or insulator, increases the capacitance of the capacitor compared to air is known as the Dielectric Constant, k and a dielectric material with a high dielectric constant is a better insulator than a dielectric material with a lower dielectric constant. Dielectric constant is a dimensionless quantity since it is relative to free space.

The actual permittivity or "complex permittivity" of the dielectric material between the plates is then the product of the permittivity of free space (εo) and the relative permittivity (εr) of the material being used as the dielectric and is given as:

$$\varepsilon = \varepsilon_o \times \varepsilon_r$$

In other words, if we take the permittivity of free space, εo as our base level and make it equal to one, when the vacuum of free space is replaced by some other type of insulating material, their permittivity of its dielectric is referenced to the base dielectric of free space giving a multiplication factor known as "relative permittivity", εr. So, the value of the complex permittivity, ε will always be equal to the relative permittivity times one.

Typical units of dielectric permittivity, ε or dielectric constant for common materials are: Pure Vacuum = 1.0000, Air = 1.0006, Paper = 2.5 to 3.5, Glass = 3 to 10, Mica = 5 to 7, Wood = 3 to 8 and Metal Oxide Powders = 6 to 20 etc. This then gives us a final equation for the capacitance of a capacitor as:

$$\text{Capacitance, } C = \frac{\varepsilon_o \varepsilon_r A}{d} \text{ Farads}$$

5.0

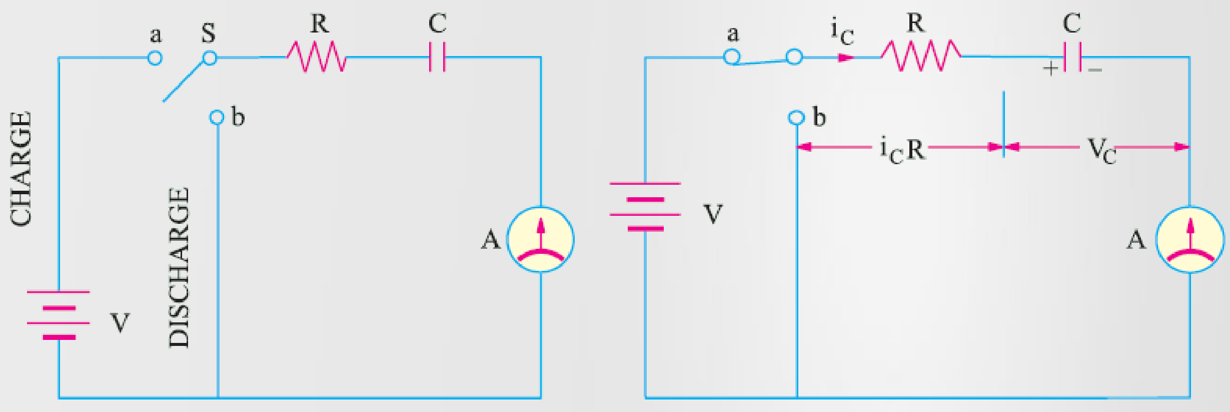
CHARGING OF A CAPACITOR

When a capacitor is connected across a dc voltage source, it will charge to a value equal to the voltage applied. If the charge capacitor is then connected across a load, the capacitor will then discharge through the load. The time it takes a capacitor to charge can be calculated if the circuit's resistance and capacitance are known. Let us now see how we can calculate a capacitor's charge time.

In Figure 5.1. (a) is shown an arrangement by which a capacitor *C* may be charged through a high resistance *R* from a battery of *V* volts. The voltage across *C* can be measured by a suitable voltmeter. When switch *S* is connected to terminal (*a*), *C* is charged but when it is connected to *b*, *C* is short circuited through *R* and is thus discharged.

As shown in Figure 5.1 (b), switch *S* is shifted to *a* for charging the capacitor for the battery. The voltage across *C* does not rise to *V* instantaneously but builds up slowly *i.e.* exponentially and not linearly. Charging current i_c is maximum at the start *i.e.* when *C* is uncharged, then it decreases exponentially and finally ceases when potential difference, V across capacitor plates becomes equal and opposite to the battery voltage *V*. At any instant during charging, let

V_c = potential difference across *C*; i_c = charging current
q = charge on capacitor plates



(a) (b)

Figure 5.1: Capacitor begin to charge when switch is closed to 'a'

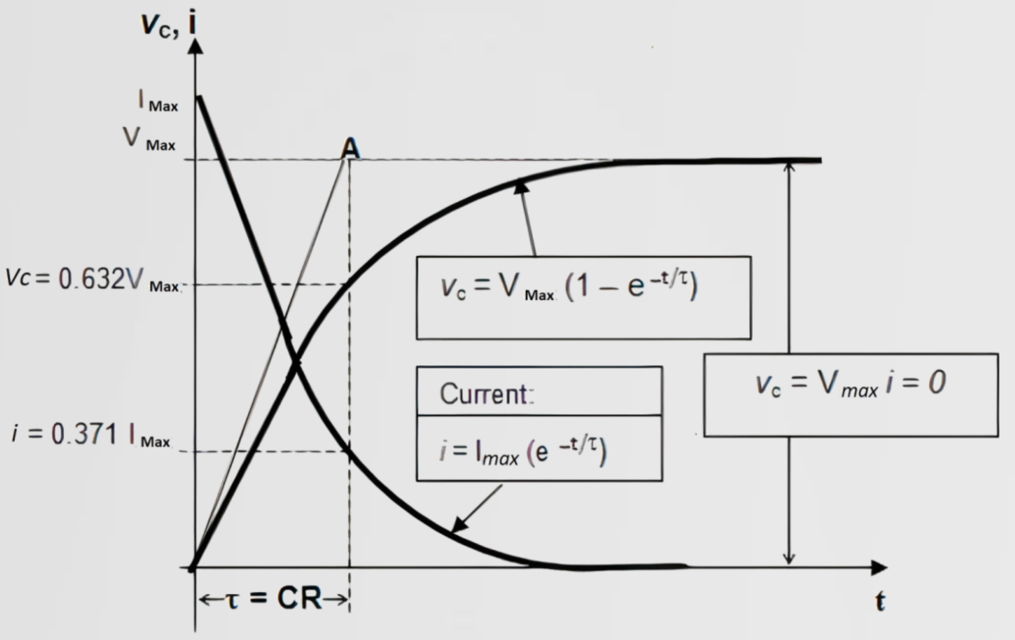


Figure 5.2: Curve diagram for current and voltage during charging process

When a capacitor is connected across a dc voltage source, such as battery or power supply, current will flow and the capacitor will charge up to a value equal to the dc source voltage as shown in the Figure 5.1. When the charge switch is first closed, there is no voltage across the capacitor at that instant and therefore a potential difference exists between the battery and capacitor.

This causes current to flow and begin charging the capacitor. When the capacitor is fully charged no potential difference exists between the voltage source and the capacitor. Consequently, no more current flows in the circuit as the capacitor to charge to the supplied voltage is dependent on the circuit's resistance and capacitance value.

If the circuit's resistance is increased, the opposition to current flow will be increased, and will take the capacitor a longer period of time to obtain the same amount of charge because the circuit current available to charge the capacitor is less. If the value of capacitance is increased, it again take a longer time to charged to maximum value because a greater amount of charge is required to build up the voltage across the capacitor to maximum value.

5.1 Time Constant, τ

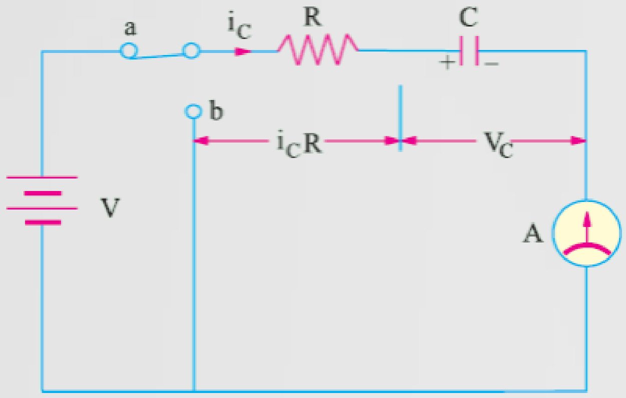


Figure 5.1 (b) : From the circuit, applied voltage, $V = i_c R + V_c$

Just at the start of charging, potential difference across capacitor is zero, hence from Figure 5.1 (b), **putting v_c = 0** in the equation of applied voltage, we get

$$V = i_c R + v_c$$

With, $$i_c = \frac{dq}{dt} = \frac{d}{dt}(Cv_c) = C\frac{dv_c}{dt} \quad \therefore \; V = v_c + CR\frac{dv_c}{dt}$$

We get, $$V = CR\frac{dv_c}{dt}$$

Therefore, initial rate of rise of voltage across the capacitor is:

$$\left(\frac{dv_c}{dt}\right)_{t=0} = \frac{V}{CR} = \frac{V}{\tau}$$

Time constant (τ) of an *R-C* circuit is defined as ***the time during which voltage across capacitor would have reached its maximum value V had it maintained its initial rate of rise.*** Mathematically, this can be stated as;

$$\tau = R \times C$$

Example 5.1 Charging Capacitor

A circuit consists of a resistor connected in series with a 0.5μF capacitor and has a time constant of 12 ms. Determine

(a) the value of the resistor,
(b) the capacitor voltage, 7ms after connecting to a 10 V supply.

Solution

$C = 0.5\mu F = (0.5 \text{ x } 10\text{-}6)$ F, $\tau = 12$ ms

(a)

$\tau = RC$

$R = \tau / C$

$= (12 \text{ x } 10^{-3}) / (0.5 \text{ x } 10^{-6})$

$= 24 \text{ x } 10^{3} = \mathbf{24\ k\Omega}$

(b)

$V_C = V\ (1 - e^{-t/\tau})$

$= 10\ (1 - e^{-7/12} \text{ x } 10\text{-}3\ )$

$= 10\ (1 - e^{-0.583})$

$= 10\ (1 - 0.558)$

$= \mathbf{4.42\ V}$

6.0

DISCHARGING OF A CAPACITOR

When a fully charge capacitor is connected across a resistor, it will discharge exponentially to 0 V. The time it takes a capacitor to discharge can be calculated if the circuit's resistance and capacitance are known. Let us now see how we can calculate a capacitor's discharge time.

As shown in Figure 6.1, when *S* is shifted to *b*, *C* is discharged through *R*. It will be seen that the discharging current flows in a direction opposite to that the charging current as shown in Figure 6.2. Hence, if the direction of the charging current is taken positive, then that of the discharging current will be taken as negative. To begin with, the discharge current is maximum but then decreases exponentially till it ceases when capacitor is fully discharged.

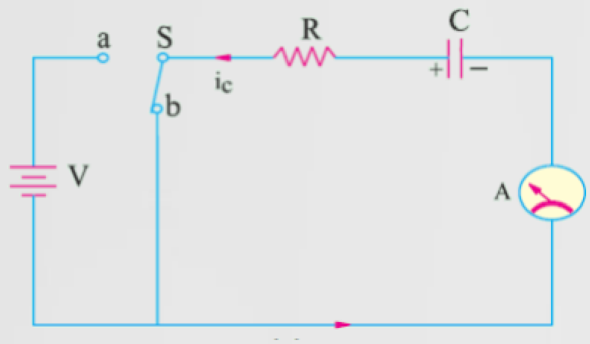


Figure 6.1 : Capacitor begin to discharge when switch is closed to 'b'

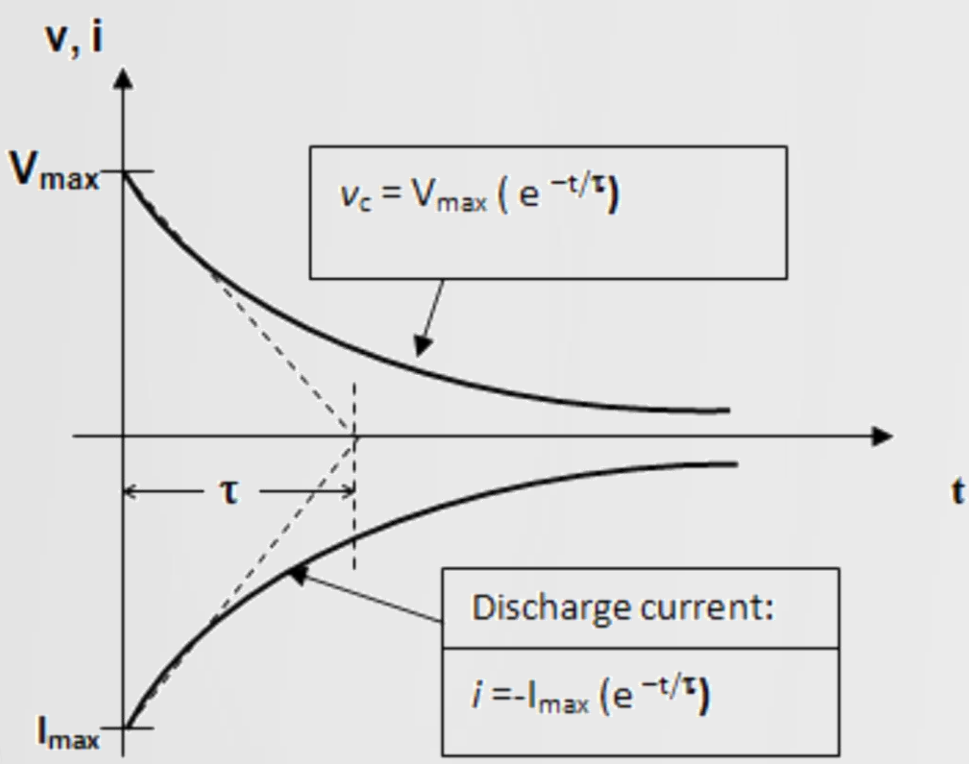


Figure 6.2 : Capacitor begin to discharge when switch is closed to 'b'

Example 6.1 Discharging Capacitor

A capacitor is charged to 100V and then discharged through a 50kΩ resistor. If the time constant of the circuit is 0.8s. Determine

a) The value of the capacitor,
b) The time for the capacitor voltage to fall to 20V,
c) The current flowing when the capacitor has been discharging for 0.5s, and
d) The voltage drop across the resistor when the capacitor had been discharging for one second.

Solution

$V = 100V$, $\tau = 0.8s$, $R = 50k\Omega = 50 \times 10^3 \Omega$

(a)

$\tau = RC$

$C = \tau / R$

$= 0.8 / (50 \times 10^3)$

$= \mathbf{16\mu F}$

(b)

$V_C = V e^{-t/\tau}$

$20 = 100 e^{-t/0.8}$

$1/5 = e^{-t/0.8}$

$e^{t/0.8} = 5$

$t/0.8 = \ln 5$

$t = 0.8 \ln 5$

$= \mathbf{1.29\ s}$

(c)

$i = I e^{-t/\tau}$ where the initial current flowing,

$I = V/R$

$= 100 / 50 \times 10^3$

$= 2\ mA$

$i = I e^{-t/\tau}$

$= 2m\ e^{-0.5/0.8}$

$= 2m\ e^{-0.625}$

$= 2m \times 0.535$

$= \mathbf{1.07\ mA}$

(d)

$V_C = V_R = V e^{-t/\tau}$

$= 100 e^{-1/0.8}$

$= 100 e^{-1.25}$

$= 100 \times 0.287$

$= \mathbf{28.7\ V}$

7.0
THE ENERGY STORED

Charging of a capacitor always involves some expenditure of energy by the charging agency. This energy is stored up in the electrostatic field set up in the dielectric medium. On discharging the capacitor, the field collapses and the stored energy is released.

The energy W stored in a capacitor is electrostatic potential energy and is thus related to the charge Q and voltage V between the capacitor plates. A charged capacitor stores energy in the electrical field between its plates. As the capacitor is being charged, the electrical field builds up. When a charged capacitor is disconnected from a battery, its energy remains in the field in the space between its plates.

Suppose at any stage of charging, the potential difference across the plates is V. By definition, it is equal to the work done in shifting one coulomb from one plate to another. If 'dq' is charge next transferred, the work done is

$$dW = v.dq$$

With, $q = Cv \;,\; dq = C.dv \;, dW = Cv.dv$

Total work done in V, $W = \int_0^v Cv.dv = C \left| \frac{v^2}{2} \right|_0^v \therefore W = \frac{1}{2} CV^2$

Therefore, $W = \frac{1}{2} CV^2 \text{ joules } = \frac{1}{2} QV \text{ joules } = \frac{Q^2}{2C} \text{ joules}$

Example 7.1 Understanding Capacitance and Energy

An air-capacitor of capacitance 0.005 μ F is connected to a direct voltage of 500 V, is disconnected and then immersed in oil with a relative permittivity of 2.5. Find the energy stored in the capacitor **before** and **after** immersion.

Solution

Energy before immersion is

$$W_1 = E_1 = \frac{1}{2}CV^2 = \frac{1}{2} \times 0.005 \times 10^{-6} \times 500^2 = \mathbf{625 \times 10^{-6}\ J}$$

When immersed in oil, its capacitance is increased 2.5 times. Since charge is constant, new capacitances is 2.5 × 0.005 = 0.0125 μF and new voltage (inversely proportional to capacitance) is 500/2.5 = 200 V. (Refer to Q=CV)

$$W_2 = E_2 = \frac{1}{2}CV^2 = \frac{1}{2} \times 0.125 \times 10^{-6} \times 200^2 = \mathbf{250 \times 10^{-6}\ J}$$

Example 7.1 Understanding Capacitance and Energy

Capacitance of a Heart Defibrillator

A heart defibrillator delivers 4.00×10^2 J of energy by discharging a capacitor initially at 1.00×10^4 V. What is its capacitance?

Solution

Solving this expression for C and entering the given values yields

$$W = E = \frac{1}{2}CV^2$$

$$C = 2\frac{E}{CV^2} = 2\frac{4.00\times102\text{J}}{(1.00\times104\text{V})^2} = \mathbf{8.00\mu F.}$$

Summary

1. A **capacitor** is a device that stores electric charge and potential energy. The **capacitance** C of a capacitor is the ratio of the charge stored on the capacitor plates to the potential difference between them:

$$C = \frac{Q}{|\Delta V|}$$

2. Isolated charged sphere of radius R

$$C = 4\pi\varepsilon_0 R$$

3. Parallel-plate capacitor of plate area A and plate separation d

$$C = \frac{\varepsilon_0 A}{\mathrm{d}}$$

4. The equivalent capacitance of capacitors connected in parallel and in series are

$$C_{eq} = C_1 + C_2 + C_3 + \cdots \quad \text{(parallel)}$$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots \quad \text{(series)}$$

5. Charging Capacitor

$$V_C = V\,(1 - e^{-t/\tau})$$

$$V_R = V\,e^{-t/\tau}$$

$$i = I\,e^{-t/\tau}$$

$$\tau = RC$$

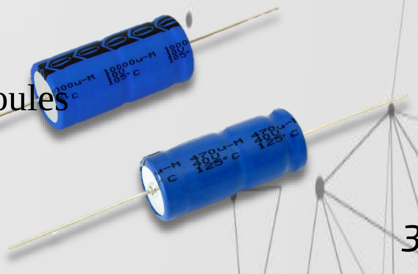
6. Discharging Capacitor

$$V_C = V_R = V\,e^{-t/\tau}$$

$$i = I\,e^{-t/\tau}$$

7. The energy stored

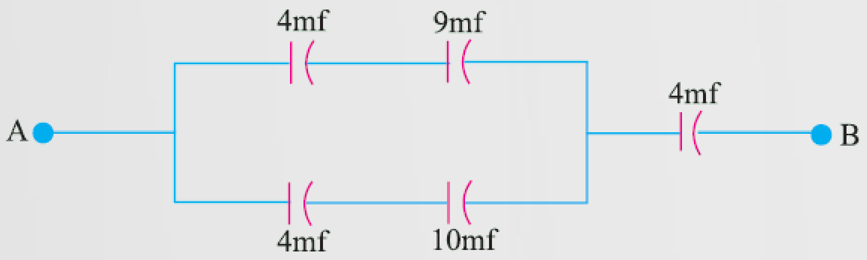
$$W = \frac{1}{2}CV^2 \text{ joules } = \frac{1}{2}QV \text{ joules} = \frac{Q^2}{2C} \text{ joules}$$



Tutorial

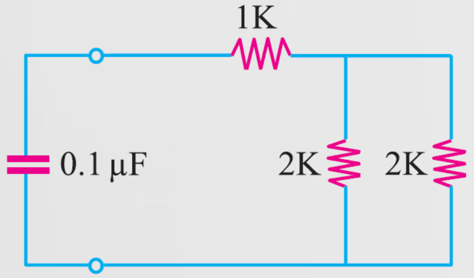
1. Derive an expression for the equivalent capacitance of a group of capacitors when they are connected
   (i) in parallel (ii) in series.

2. Find the equivalent capacitance between the points A and B of the network shown in Figure 1 below.



3. Three capacitors of 1, 2 and 3 micro farads are connected in series across a supply voltage of 100V. Find the equivalent capacitance of the combination and energy stored in each capacitor.

4. Find the time constant of the circuit shown in Figure 2 below.
   [200 μS].



5. An 8 μF capacitor is being charged by a 400 V supply through 0.1 mega-ohm resistor. How long will it take the capacitor to develop a potential difference of 300 V ? Also what fraction of the final energy is stored in the capacitor ? **[1.11 Second, 56.3% of full energy]**

6. When a capacitor, charged to a potential difference of 400 V, is connected to a voltmeter having a resistance of 25 MΩ, the voltmeter reading is observed to have fallen to 50 V at the end of an interval of 2 minutes. Find the capacitance of the capacitor. **[2.31 μF]**

References

Liao, S., Dourmashkin, P., & Belcher, J.W. (2004). *Capacitance and Dielectrics.* https://web.mit.edu/8.02t/www/802TEAL3D/visualizations/coursenotes/modules/guide05.pdf

Anonymous. (n.d.). *Introduction to Capacitors*. https://www.electronics-tutorials.ws/capacitor/cap_1.html

Shrooq, S. (n.d). *Capacitance*. https://www.academia.edu/32653032/Capacitance?email_work_card=view-paper

Samuel, J.L., et al. (n.d). *Capacitance*. https://openstax.org/books/university-physics-volume-2/pages/8-3-energy-stored-in-a-capacitor

POLITEKNIK MALAYSIA
KUALA TERENGGANU

e ISBN 978-967-2240-38-9

9 7 8 9 6 7 2 2 4 0 3 8 9

CAPACITOR AND
CAPACITANCE